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ABSTRACT

Teachers describe their professional development experiences regarding science, science teaching, and science learning as they occurred over a 2.5 year period in the Literacy in Science and Social Studies Project in a professional development school setting. They contrast their experiences in this collaborative setting with more traditional models of science education reform. The members of the Literacy in Science and Social Studies Project pursued their goals through a variety of activities including study group discussions, curriculum planning, co-teaching of elementary children and preservice teachers, and joint research on student and educator learning. In this paper, the teachers, university professors, and doctoral students use stories of their professional development in science to illustrate two themes that emerged from their work in this restructured context. First, there is the theme of increasing interest in science over time as those who initially were science-avoiders found entryways into science. The second theme is that the science educators' research, teacher education efforts, and elementary school science teaching was enriched by their regular interactions with professional whose expertise and interest were in subject matter areas other than science. The teachers illustrate how their relationships with science changed over time. Science-avoiders became comfortable with and challenged by their own learning of science and their students' ways of thinking in science. Science educators deepened their understanding of science as a socially constructed endeavor. Professional development for elementary teachers in the area of science is perhaps more meaningful when it fits with the individual's readiness to tackle this subject area. (MDH)

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# ENTRYWAYS INTO SCIENCE AND SCIENCE TEACHING: TEACHER AND RESEARCHER DEVELOPMENT IN A PROFESSIONAL DEVELOPMENT SCHOOL

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Elaine Hoekwater, Carol Ligett,
Barbara Lindquist, Kathleen Peasley,
and Cheryl L. Rosaen

**Center for the Learning and Teaching of Elementary Subjects**

**Institute for Research on Teaching**

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## Center for the Learning and Teaching of Elementary Subjects

The **Center for the Learning and Teaching of Elementary Subjects** was awarded to Michigan State University in 1987 after a nationwide competition. Funded by the Office of Educational Research and Improvement, U.S. Department of Education, the Elementary Subjects Center is a major project housed in the Institute for Research on Teaching (IRT). The program focuses on conceptual understanding, higher order thinking, and problem solving in elementary school teaching of mathematics, science, social studies, literature, and the arts. Center researchers are identifying exemplary curriculum, instruction, and evaluation practices in the teaching of these school subjects; studying these practices to build new hypotheses about how the effectiveness of elementary schools can be improved; testing these hypotheses through school-based research; and making specific recommendations for the improvement of school policies, instructional materials, assessment procedures, and teaching practices. Research questions include, What content should be taught when teaching these subjects for understanding and use of knowledge? How do teachers concentrate their teaching to use their limited resources best? and In what ways is good teaching subject matter-specific?

The work is designed to unfold in three phases, beginning with literature review and interview studies designed to elicit and synthesize the points of view of various stakeholders (representatives of the underlying academic disciplines, intellectual leaders and organizations concerned with curriculum and instruction in school subjects, classroom teachers, state- and district-level policymakers) concerning ideal curriculum, instruction, and evaluation practices in these five content areas at the elementary level. Phase II involves interview and observation methods designed to describe current practice, and in particular, best practice as observed in the classrooms of teachers believed to be outstanding. Phase II also involves analysis of curricula (both widely used curriculum series and distinctive curricula developed with special emphasis on conceptual understanding and higher order applications), as another approach to gathering information about current practices. In Phase III, models of ideal practice will be developed, based on what has been learned and synthesized from the first two phases, and will be tested through classroom intervention studies.

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## Abstract

The authors describe their professional development experiences regarding science, science teaching, and science learning as they occurred over a 2 1/2 year period in the Literacy in Science and Social Studies Project in a professional development school setting. They contrast their experiences in this collaborative setting with more traditional models of science education reform. A key difference between this collaborative model of reform and more traditional approaches is the empowerment of teachers to make decisions and plans regarding their professional growth. Instead of responding to mandates from administrators, state government, or educational reformers, teachers in this setting were given responsibility for planning their own professional growth in collaboration with school-based and University-based peers. The members of the Literacy in Science and Social Studies Project pursued their goals through a variety of activities including study group discussions, curriculum planning, co-teaching of elementary children and preservice teachers, and joint research on student and educator learning. Each group member began the project with an interest in exploring a particular subject matter area (social studies, language arts, or science) but eventually found an entryway into science.

In this paper, the teachers, university professors, and doctoral students use stories of their professional development in science to illustrate two themes that emerged from their work in this restructured context. First, there is the theme of increasing interest in science over time as those who initially were science-avoiders found entryways into science--different entryways for each person. All three teachers, for example, chose during the second year of the project to reclaim responsibility for teaching science (in lieu of arranging for a colleague to teach science) and became intrigued with teaching science for understanding. This interest in science evolved gradually and emanated from *teachers'* decisions, not dictates from above.

The second theme is that the science educators' research, teacher education efforts, and elementary school science teaching was enriched by their regular interactions with professionals whose expertise and interests were in subject matter areas other then science. There were multiple ways in which the perspectives of language arts-focused and social science-focused members of the group challenged the science educators' ideas about science, about science curriculum, and about science teaching and learning.

In sharing stories of their professional development in science, the authors illustrate how their relationships to science changed over time. Science-avoiders became comfortable with and challenged by their own learning of science and their students' ways of thinking in science. Science educators deepened their understanding of science as a socially constructed endeavor. Looking across the stories, the authors conclude that professional development for elementary teachers in the area of science is perhaps more meaningful when it fits with the individual's readiness to tackle this subject area. It is easier to explore teaching for understanding in science after exploring similar issues first in a subject area that is more comfortable for the learner. In addition, these experiences illustrate the potential power of cross-disciplinary teams of educators.

# ENTRYWAYS INTO SCIENCE AND SCIENCE TEACHING: TEACHER AND RESEARCHER DEVELOPMENT IN A PROFESSIONAL DEVELOPMENT SCHOOL[1]

Kathleen J. Roth, Corinna Hasbach, Constanza Hazelwood, Elaine Hoekwater, Carol Ligett, Barbara Lindquist, Kathleen Peasley, and Cheryl Rosaen[2]

## Introduction

### Traditional Models of Reform for Elementary Science: A Science Curriculum Focus

Logically enough, traditional efforts to reform elementary science instruction focus directly on changing the science curriculum and teachers' preparation for teaching that science curriculum. Current efforts at both state and national levels fit this paradigm. For example, the National Science Foundation has funded curriculum materials development projects that are focused on creating new visions of elementary science curricula (BSCS [Biological Sciences Curriculum Study], 1992; Jaffe & Buika, 1990; Linn & Songer, 1989; Technology Education Research Center and National Geographic Society, 1990). The American Association for the Advancement of Science (AAAS) Project 2061 is focused on defining new curricular goals and curriculum models for K-12 science instruction (AAAS, 1989). The National Association of Science Teachers recently sponsored a conference designed to reform elementary science teaching. The conference, *A Strategy for Change*, brought together teams of educators from school districts across the country and supported these teams in considering how to launch science reform at the elementary level. The National Center for the Improvement of Science Teaching has created a series of

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[1]An earlier version of this paper was presented at the annual meeting of the National Association for Research in Science Teaching, Boston, March 1992.

[2]Kathleen J. Roth, associate professor of teacher education at Michigan State Univeristy, is a senior researcher with the Center for the Learning and Teaching of Elementary Subjects. Corinna Hasbach and Constanza Hazelwood, doctoral candidates in teacher education at MSU, are research assistants with the Center. Elaine Hoekwater teaches fifth grade, Carol Ligett third grade, and Barbara Lindquist fifth grade at an MSU Professional Development School. Kathleen Peasley, a doctoral candidate in teacher education at MSU, is a research assistant with the Center. Cheryl L. Rosaen, assistant professor of teacher education at MSU, is a senior researcher with the Center. The authors work together in the Literacy in Science and Social Studies Project at an MSU Professional Development School.

synthesis reports about elementary and middle school science curriculum, science assessment, and science teacher preparation and development (National Center for Improving Science Education, 1989a, 1989b, 1989c). In the state of Michigan, elementary science reform is currently centered around the development of new state science objectives and accompanying teaching materials designed to support teachers in preparing students for state science assessment tests (Michigan State Board of Education, 1991). A Michigan law, Public Act 25, requires school districts to develop core curriculum statements for science and other subject matters. All of these efforts focus directly on *science* curriculum reform. A very logical argument can be made for this approach. If elementary science teaching is in need of change (and there are many sources of evidence that it is), it makes sense to attack the problem directly by focusing energies on science curriculum reform and on the preparation and development of science teachers.

A Collaborative Model of Reform: Focus on Contexts and Norms of Professional Development

We have been investigating a different model of reform, a model that is focused on changing school cultures, norms, and professional roles. This is a collaborative model of educational reform in which educators in K-12 schools and teacher educators/researchers at universities work together to improve both teaching and learning in schools and the professional development of teachers and preservice teachers. The initial focus is not on reforming curriculum and teaching in a particular subject matter (such as science). Instead, the focus is on creating new structures and roles that will empower classroom-based educators to become inquiring, thoughtful practitioners who have the time, support, and commitment to become professionals who can generate new knowledge needed to effect dramatic improvements in K-12 student learning and in teacher education (Barth, 1990; Elmore, 1990; Fullan, Bennett, & Rolheiser-Bennett, 1990; Hargreaves & Dawe, 1990; Holmes Group, 1990; Joyce, 1990; Kincheloe, 1991; Kreisberg, 1992; Little, 1987, 1990; Murphy, 1991; Rowan, 1990; Russell & Munby, 1992). Our reform model centers around the creation of a professional development school in which university and school faculties collaborate to inquire systematically into critical issues in teaching and learning, to try new approaches to teaching, learning, and the organization of schools, and to create "realistic,

challenging, and supportive settings for the field studies of prospective teachers and for the rising professionalism of practicing teachers" (Holmes Group, 1990, p. viii).

In this model of reform, educators in schools take on more leadership and professional responsibility in defining local needs and in restructuring the school culture and context to design appropriate professional growth opportunities and to develop questions to be investigated through teaching and research efforts. Similar to movement in the business-manufacturing community from models based on hierarchical management and competition among workers to models based on worker involvement in management through cooperative quality circles (Schenkat, 1992), this collaborative model of reform in education emphasizes the professional status and responsibility of the classroom-based educators. Classroom educators, in this model, are no longer workers who need training to meet the objectives set down from above (district leaders, state legislators, the National Science Foundation, etc.). Instead, they are professional leaders who conduct their own inquiry and take charge of their own professional development. Local collaborative teams define needs, priorities, and plans of action.

Such a model can be frightening to science educators. Numerous studies indicate that elementary teachers frequently have limited science backgrounds and that science is not taught frequently at the elementary level because many teachers feel ill prepared to teach science and/or do not like science (Coble & Rice, 1982; Fulton, Gates, & Krockover, 1980; Horn & James, 1981; Weir, 1987; Weiss, 1978, 1987). If these elementary teachers are allowed to take charge of designing appropriate science curriculum goals for their students, won't science disappear completely from the elementary curriculum? Research in science education is showing that teaching science for understanding is a difficult and challenging task (Anderson & Roth, 1989; Marton & Ramsden, 1988; Minstrell, 1984; Smith, E.L., 1983; Smith, D.C., 1992; Smith & Neale, 1991). Will elementary teachers choose to take on such a task without some external incentives such as assessment tests, state objectives, district core curriculum statements, etc.?

Context and Theoretical Framework for the Study: A Collaborative Model of Reform

To explore both the problems and possibilities of such a collaborative model of reform, we began three years ago working together as a group of educators in a professional development school context. In this setting, we created a project called the Literacy in Science and Social Studies Project (LISSS). Participants in this project include three classroom educators from Emerson Elementary School,[3] three doctoral students at Michigan State University, and two assistant professors from Michigan State University. The group came together after a series of meetings and an intensive two-week Summer Institute during spring and summer, 1989 in which a much larger group of school-based educators and interested university-based educators talked about their particular interests and clarified visions of what we wanted this professional development school to become. At the end of these negotiations, we had developed a mission statement for our overall efforts and created three projects which represented our first efforts to work toward our overall goals. The Literacy in Science and Social studies Project was one of the three projects (along with the Math Study Group and the Developmentally Appropriate Curriculum Project) that began the effort to create a professional development school (PDS) that would enact our mission:

> The mission of Emerson Professional Development School is to provide students, prospective teachers, and practicing educators opportunities to use learned knowledge to interpret new situations, to solve problems, to think and reason, and to build new knowledge structures. Professionals at Emerson School and Michigan State University working together as a community of learners will create an equitable learning environment that will promote educational growth and development as lifelong processes. To achieve these goals in meaningful ways will require creative thinking about organizational structures and professional roles. Collaborative study will permit the development of deeper understanding of persisting educational problems and foster a questioning stance. This collaborative relationship is based upon mutual respect and appreciation for the expertise of all concerned in an effort to build an exemplary educational extension network for the 21st century.

Beginnings: The Invisibility of Science in the Literacy in Science and Social Studies Project

When our Literacy in Science and Social Studies Project group began meeting regularly in 1989-90, each individual brought unique experiences, perspectives, and interests. What we shared

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[3]Names of school, students, and city are pseudonyms.

in common was a desire to explore ways of engaging students more genuinely in meaningful learning. Each of us wanted students to be more involved in their learning, and we were all intrigued with the idea that different modes of classroom talk and writing might enhance subject matter learning.

Given the title of our project, it is interesting that all but three of the participants shared an additional characteristic: None of the classroom teachers was teaching science and none was particularly interested in pursuing questions about science teaching and learning. For most members of the group, the "science" in our project title was invisible. Elaine Hoekwater, for example, was responsible for teaching social studies for the three fifth-grade classes, and she wanted to study and improve her social studies teaching practice. Barbara Lindquist was teaching "English" for the three fifth-grade classes and was dissatisfied with the grammar focus in her teaching of writing. Through her work on the district Communication Arts committee, she became interested in process writing approaches and wanted to pursue new ways of teaching students to become more independent writers. Like Elaine and Barbara, Carol Ligett had arranged for another teacher to instruct her third graders in science. In the third-grade team, Carol was the social studies expert, teaching social studies to three groups of third graders. Yet she was bored with the "communities" focus of the social studies textbook and was intrigued with the idea that third graders could pursue more thought-provoking social issues and questions. She also was interested in exploring more meaningful ways to involve third graders in writing both in social studies class and in language arts time. Cheryl Rosaen had been a high-school and middle-school English teacher and had maintained a focus on language and literacy development in her teacher education and research work at MSU. Corinna Hasbach also came from an English teaching background. In her doctoral studies at MSU, she was developing a cognate in feminist perspectives in teacher education.

Only three members of the group began the project with a particular interest and expertise in science--Kathy Roth, Constanza Hazelwood, and Kathleen Peasley. These project members, who were all affiliated with the university, cared a great deal about the "science" in our project title; in

fact, science had been negotiated into the title to reflect their interests and potential contributions to the group. Although these three participants brought a science interest and expertise to the group, science was never formally put on everyone's agenda. Unlike traditional science reform efforts, participants were not required to "care" about and focus attention on science issues. In contrast, our model of professional development encouraged each team member to pursue her own particular interests. Each of us had our own goals and questions about a subject matter area that was most comfortable to investigate.

The three of us interested in science education began this collaboration with enthusiasm but also with many questions. We were determined not to force our interest in science on others in the group, but we wondered if science would ever become an issue of interest to the group. Would our knowledge and experiences in science help other participants think about similar issues in social studies and writing? How much should we talk about our science interests and experiences? We were each interested in conducting classroom research on student learning in science, and we also wanted to do some elementary teaching of science. If the teachers in our group were not even teaching science, would we be able to pursue our interests? Was this going to be a productive collaboration, or were we going to need to search out a new team whose subject matter interests were more closely matched?

Two Emerging Themes

The story we have to tell of our progress over the last two and a half years has two important themes. First, there is the theme of increasing interest in science over time--at different rates and in different ways for each person--by those who initially were science-avoiders. All three teachers, for example, chose eventually to take on the responsibility for teaching science for their students and have become intrigued with teaching science. This interest in science was not dictated to the teachers by an administrator or by the university members of the group. Instead, it evolved gradually over time in the context of the collaborative work. It was the *teachers'* decisions.

The second theme is that the science educators' research, teacher education efforts, and science teaching was enriched by their regular interactions with professionals whose expertise was

in subject matter areas other than science. Although the science educator members of the group initially expected to serve as science consultants for the group, they were each surprised at the multiple ways in which the perspectives of the nonscience members of the group challenged their ideas about science, about science curriculum, about science teaching and learning, and about teacher learning.

In this report we share stories illustrating how individual participants' relationships to science and science teaching changed over time. From these stories, we propose the argument that professional development for elementary teachers in the area of science is more meaningful when it fits with the individual's readiness to tackle this subject area. It is easier to explore teaching for understanding in science after exploring similar issues first in a subject area that is more comfortable for the teacher as learner.

Collaborative Structure and Philosophical Orientation of the LISSS Project

During the first year of the project (1989-90), the group met weekly for a two-hour study group session, with co-teachers hired to provide this reassigned time for teachers. The study group explored different visions of teaching for understanding in writing, social studies, and science. We examined the role that writing and discourse might play in such visions. Study group sessions centered around joint examination of shared readings of research articles, videotapes of classroom teaching, examples of student writing, etc. First-year efforts also included substantial work in subgroups developing ideas and resources to enable each teacher to try some significant changes in one instructional unit. University and school-based group members co-planned the units and developed strategies for studying the effects of the units through interviews, observations, and pre- and posttests. The school-based educators then taught the units in the spring with the university participants acting as support persons and documentors. The fifth-grade units focused on social studies and writing, as the two teachers attempted to integrate the students' study of the Civil War with their experiences in writing. The third grade unit was designed as a social studies unit focused around the idea of "community" through the study of prehistoric

peoples. As we shall see, this unit gradually became as much a science unit as a social studies unit.

Work during the second year (1990-91) focused on understanding and using "research *for* teaching" (Noddings, 1986) with each project participant taking on some version of a teacher-researcher role. Teachers, researchers, and graduate students co-planned and co-taught in two fifth grade classrooms and a third-grade classroom to create a series of case studies in science, social studies, and writing. We studied both our students' learning and our own learning over the course of the year.

Our shared experiences in taking on the teacher-researcher role enabled us to inquire about meaningful questions and problems of practice that emerged out of actual curriculum development and classroom teaching. We wanted all participants' voices, questions, and interpretive frames to become part of the research process (Cochran-Smith & Lytle, 1990). This work contributes to a growing body of research investigating the power of teacher-researcher collaborations to improve practice and extend the professional role (Strickland, 1988), research on the role of teacher-researcher collaborations in building new theories of teaching and learning (Cole, 1989), and research on teaching and learning in science, social studies, and writing classrooms (Anderson & Roth, 1989; Graves, 1983; Parker, 1989).

We structured our collaborative arrangement around assumptions that all participants had valuable contributions to make to both teaching and research and that all participants had further learning to do about research, about teaching of subject matter, and about students as sense makers. We intended the relationship to be symbiotic, interdependent, and mutually beneficial (Cole, 1989). In addition, we tried to reconceptualize the role of research in education, to find ways for research to serve and support practice not just be about practice. The closer we can come to conceptualizing teaching as research (Hollingsworth, 1990), the greater the chances of it becoming an integral and meaningful tool for improving practice. Without research as an important part of practice, important experiences could go unnoticed and unexamined.

## Research Design: Studying Our Own Learning

To study our growth as a project and as individual educators, we took a collaborative approach to data collection. Weekly study group meetings across a two-year period (1989-1991) were audiotaped, with field notes supplementing the audio recordings. Curriculum planning group meetings across the two years were also audiorecorded; written notes and documents created before, during, and after planning sessions were saved. Classroom teaching was studied through regular observations of each other. Classroom observations were documented using a variety of strategies including audiorecording, field notes, videotaping, and collection of student and teacher written documents. Such classroom documentation was intensive during target units of instruction across the two years. In addition, teacher-researchers wrote about their experiences in journals and in the professional development school newsletter. We also co-constructed interview questions to ask students and to ask each other. Interviews with students helped us assess their learning in science, social studies, and writing across each of the two years. We interviewed each other at key points across the two year period to document our changes and growth.

To analyze our changing conceptions of science teaching and learning, Roth and Peasley took a historical approach to revisit the data set. We used field notes and transcripts of study group sessions to create a time line of occasions when science teaching and learning were discussed and by whom. We noted the kinds of questions and understandings that each participant was expressing. The transcripts of our interviews with each other were also examined and combined with data from the study group sessions to create a time line of science-related events for each individual participant. This analysis traced each participant's questions, talk, and writing about science across the two-year period.

Finally, each participant drew from the data to write or tell orally her personal story of the evolution of her thinking about science and science teaching from Fall 1989 until the present time (almost a three-year period). These stories are presented in this paper. They are organized in two clusters to illustrate our two main themes. The first group describes those participants who began the project with little or no interest in science. Their stories describe the multiple ways that these

participants found entryways into science through participation in this collaborative project. The second group of stories describes the science educators, those participants who began the project with a primary interest in science teaching and learning. Their stories illustrate how the perspectives of nonscience project members challenged their thinking about science and about science teaching and learning.

## The First Theme: Science-Avoiding Participants Find Entryways into Science and Science Teaching

### Carol's Story--Books as an Entryway to Science

When I entered my student teaching experience 25 years ago, I was especially worried about science. My cooperating teacher's husband had been my high school science teacher. Did Mr. Ruska remember what a terrible science student I was? Throughout student teaching I worried about what my cooperating teacher was thinking about my science knowledge and my science teaching. Did she know that science was the only class in college in which I received a D? I had made a private oath that if I ever got a D in a course, I would retake it. But I happily took my D in chemistry and never returned--I was worried I might fail it a second time around. Besides, all those A's in writing and literature classes would pull up my average.

When I started teaching at Emerson, a colleague also teaching third grade helped me continue my pattern of science avoidance. She loved science and offered to teach science for all the third graders if I would teach the social studies. I took her up on her offer without a moment's hesitation! After all, I did not feel qualified to teach science because of this D. It seemed to me that I was just getting worse in science as time went on--a C from Mr. Ruska in high school and then a D in college! Besides the negative impression of science from these course experiences, I also had a negative stereotype of science as this lab thing with lots of bunsen burners and beakers and messiness. I was happy that my friend and colleague solved the problem for me by teaching science to my third graders.

When the LISSS Project began, I was close to burnout as a teacher. I remember thinking how bored I was with the curriculum, and the song "Is That All There Is?" would run through my mind as the afternoons in my classroom seemed interminable. I was the social studies teacher for

three third-grade classes, but it just all seemed so mechanical and dictated by others--the text, the district guidelines. I was having trouble connecting with the communities content, and I know the third graders were at least as bored as I was. A key event in the first year of our work together in the LISSS Project was reading critiques of the early elementary social studies curriculum from nationally prominent "experts" like Diane Ravitch (1988), Kieran Egan (1985), and Walter Parker (1989). They validated my feelings of boredom and frustration, suggesting that the social studies curriculum's focus on family and communities was not only boring for young children but "vacuous" (Ravitch, 1988). As we discussed these ideas in a social studies methods class for prospective teachers that I was co-teaching with Kathy Roth on campus and as we talked in our LISSS study group about teaching for understanding, I became excited about trying some new approaches to social studies teaching.

With the support of my LISSS colleagues and the OK from central administration to try some new things in a professional development school, I decided to approach the concept of "communities" from a totally new perspective--thinking about the first humans and how they developed communities. This idea came from a personal interest I had developed in prehistoric people from a novel I had read by Jean Auel (1980), *Clan of the Cave Bear*. In working with Kathy and Constanza in planning this unit, I left the textbook behind and started reading widely about prehistoric people, trying to find ways to help students really understand and appreciate important concepts about interdependence in communities by studying a context quite remote from their experience instead of one in which they lived everyday (Egan, 1985). A quote from Bruner in an article we had read by Ravitch resonated with my gut feelings about how to connect students with these ideas in meaningful ways:

> Whatever we know about memory, thought, passion, or any other worthy human process tells us that is not the known and the settled but the unknown and the unsettled that provokes the use of mind, the awakening of consciousness. (Bruner cited in Ravitch, 1988, p. 39)

I not only read widely, I became a bookaholic, frequenting bookstores often and buying all kinds of children's books and adult books that would help me think about this unit. Initially, I didn't realize that my unit had anything to do with science. My first clue came when I happened to

take the back door out of the bookstore one day, walking past the science section. There on the shelf was a book I had been searching for by Leakey (1977)! I had been looking for this book for a long time but had always looked in the history section. You cannot imagine how shocked and betrayed I felt to find the Leakey book in the science section. I was not a science person!

Since that fateful day, Kathy and Constanza and Barb have continually pointed out to me the ways in which my prehistoric people unit had as much science in it as it did social studies. As we studied about three early human cultures, we kept a posted list of the kinds of evidence that had been accumulated to find out about human life so long ago. For example, in one activity the children examined cave paintings and constructed charts describing the conclusions they could make from this source of evidence ("Things We Know for Sure") and the tentative inferences they could make ("Things That Might be True"). A spirited discussion ensued as children proposed and defended their interpretations of the paintings. This led to some fairly sophisticated reflections about the nature of scientific inquiry and the roles of imagination and evidence in constructing scientific explanations. We compared cave paintings as a source of evidence to other kinds of evidence--bones, fossils, rock layers, remains preserved in ice or amber.

Perhaps the realization that I was teaching science in my prehistoric people unit was the nudge I needed to try taking on science teaching with my third graders in the second year of our project. After all, our project did have "science" in the title. As part of our restructuring efforts, I was teaching half time that second year, teaching third grade half the day and participating in research and teacher education activities half the day. In the teaching part of my day, I decided to take responsibility for writing, science, and social studies instruction to match our project emphases. I looked for ways to meaningfully integrate our study in these areas.

Teaching science by myself for the first time in many years was quite frightening. I started with a social-studies focus, helping the third graders explore our world through maps and stories of explorers. From there, I tiptoed into science through an exploration of the universe. As I edged my way into teaching science, I discovered that I appreciated science--and was even fascinated with science--when it was meaningful and useful to me. And I don't mean useful in the sense of

helping me in my daily life. I mean useful in the sense of helping me figure out more about myself and my place in the world.

In that second year of our work together, I frequently found myself surprised at how interested I could be in science. For example, as I explored the universe with the third graders, I found myself totally absorbed by the ideas being raised in my reading and in my discussions with the children. By now, I had become fascinated with listening to kids' thinking and ways of making sense. Their ideas astounded me and pushed my thinking! I realized how passionately involved I had gotten in this study of the universe one day when I was supposed to be Christmas shopping and instead found myself locked in a room reading about black holes. I just couldn't get away from this study of the universe! I tried to physically escape this absorption by driving up to the grocery store. But even in the car, I couldn't get away from it! As I was driving along, I kept noticing the moon and remembering one of my student's observations about how the moon seems to follow you as you drive along in the car. I found myself trying to make sense of his observation as I drove to the store. And when I drove home, the moon seemed to be in a different location! I found myself wanting to drive in a way that would allow me to catch the moon. I felt very connected to Tommy's thinking, and I, too, was raising lots of questions.

Two things seemed to be critical in allowing me to enter into the neighborhood of science in a meaningful way--my love of books and the freedom I gave myself through this collaborative PDS work to create curriculum based on students' needs and interests (and my own) instead of being tied to textbooks and guidelines handed down from above. This summer I read Stephen Jay Gould's (1991) *Bully for Brontosaurus*. I remember commenting to my husband that his father, who has a PhD in chemistry, would appreciate this book I was reading. My husband's reaction was that I couldn't possibly be reading a book that would be of interest to a scientist. I thought hard about that comment and realized that this was a challenging, thought-provoking book that is not the type of book that most people expect elementary teachers to be reading. It helped me reflect on how important books had become in enabling me to relate to science. Books were helping me answer *my* questions about science. Realizing that I can learn and understand important ideas

related to science has opened up a whole world for me. It has opened up a whole new set of ideas and concepts. And these ideas are interesting to me and to my students.

This year, science has become even more embedded and integrated with social studies and language arts in my third-grade classroom. I have experimented with taking a literature approach to teaching science with my third graders. For example, in the prehistoric people unit, we are exploring many different kinds of books that have been written about prehistoric life. We are examining fiction as well as nonfiction, talking about the author's purpose and the author's knowledge. I am supporting students in becoming critical readers of text and encouraging them to become writers about science. We look closely at the books we share: Is the author using evidence in a scientific way or is the author more interested in creating an entertaining story? Is the author contributing to misconceptions and stereotypes of prehistoric people? Does the author's story help us have more empathy and understanding of what it might have been like to be one of the earliest humans? Does it promote the sense of wonder? As I teach the prehistoric people unit in this way, I am constantly comparing this approach with more science-focused approaches I have taken over the last two years. Will books provide an entryway into science for more students than my more "scientific" approach?

Corinna's Story--Feminism as An Entryway into Science

> We know ourselves to be made of this earth. We know this earth is made from our bodies. For we see ourselves. And we are nature. We are nature seeing nature. We are nature with a concept of nature. . . . All that I know speaks to me through this earth and I long to tell you, you who are earth too, and listen as we speak to each other of what we know: the light is in us. (Griffin, 1978, pp. 226-227)

At the beginning of our project work I remember being disengaged from science. As a student, science had never been an area of study that intrigued me. It always seemed so cold, objective, and disconnected from me. In contrast, literature was so rich with ideas and emotions, and I could connect to it in very personal ways. In fact, making personal connections was encouraged and rewarded by my literature teachers in school. So I pursued studies in literature and social sciences and avoided science as much as possible. In our Literacy in Science and Social Studies Project, I definitely saw myself as a person who could contribute to our efforts in literacy

and social studies realms but not in science. That was the realm of Kathy Roth, Kathy Peasley, and Constanza! So when our project first began, I largely ignored the science part. But then I heard Kathy Roth talking about the idea that there are different interpretations in science. That idea caught my attention--it seemed very different from the perspective I had of science as a discipline that had (or was searching for) all the answers--clear-cut, objective, proven answers. For me, the idea that there were different interpretations and perspectives in science was my link with literature. What I loved about literature in English classes when I was in school was that you could interpret one event in many, many ways. When Kathy started talking about science like that, I started thinking, "If only I had been taught science in that way, I would have been hooked in!" There have been feelings of anger as I realize that in my experiences as a student, science was presented in ways that made it inaccessible to me. I find myself envious of our fifth graders' opportunities to connect with science in so many different ways that are all valued in the classroom community.

Now my entryway into science is from an ecofeminist perspective--the link between nature and feminism. What does this perspective, this way of interpreting the world, have to contribute to science? Because of the opening to science that was created for me in this group, I have read and felt comfortable sharing with Kathy and Constanza books like *The Death of Nature: Women, Ecology and the Scientific Revolution* (Merchant, 1980), *Women and Nature--the Roaring Inside of Her* (Griffin, 1978), and *The Chalice and the Blade: Our History, Our Future* (Eisler, 1987). These books and others helped me see how the disciplines are connected from a feminist perspective, and that has become my hook into various disciplines that I would not normally think of as *my* areas. A variety of disciplines--including science--have now become important to me from my feminist perspective. Through our work together, I have become aware that my perspectives are helpful to the science participants in the group, especially as we think about how to make science more inviting to girls and other students who are traditionally shut out or turned off by science.

A critical incident related to science that reinforced this idea that *I* could contribute to the group's thinking about science centered around a pig pluck dissection that Elaine and Constanza

and a co-teacher, Nancy, were going to do with the fifth graders. The dissection was part of the district's health curriculum, and Elaine had been doing it for several years. Constanza brought me in as a resource person for the dissection. She got me thinking about how I could be helpful in thinking about the dissection even though I am not a "science" person. This was a key event for me--to realize that I could make a contribution in thinking about science teaching. Constanza was concerned that the activity of dissecting was not pedagogically sound. We talked extensively about that and shared readings about the controversy over dissection and the use of animals in both research and education. What was fascinating to me was that Elaine and Nancy--the two classroom teachers involved--both said they had always felt uncomfortable about doing dissections but felt they were required to do them. There was this discomfort that had never been articulated. This incident enabled me to be a resource person in an area that is not "my thing." I was able to look at the dissection issue in science from both a philosophical, feminist perspective, and from a pedagogical perspective. Constanza challenged my thinking from a scientific perspective. My questions and ideas helped the four of us make decisions that involved students in the controversy in meaningful ways. We asked them how they felt about dissection and found that many of them were uncomfortable with doing the dissection. We linked this issue to ideas they had been discussing in social studies: Is the way animals are used in research a form of discrimination? So the four of us were there talking with the students and making links. The students who were uncomfortable were given opportunities to think and talk about their uneasiness instead of simply being labeled "sissies" by their friends. They were also given a choice to do either the pig dissection or an intriguing simulated frog dissection on the computer. They were not simply "left out" of science (like I often had felt in my schooling) because of a due concern for animals.

Thus, my entryway into science came through the idea of perspective. My active participation in science planning regarding the pig intestines dissection helped me see that my feminist and philosophical perspectives and my comfort with multiple interpretations (developed in the context of interpreting literature) could contribute to others' thinking about science teaching and learning.

Cheryl's Story--Children's Thinking as an Entryway into Science

> The classroom has all the elements of theater, and the observant, self-examining teacher will not need a drama critic to uncover character, plot, and meaning. We are, all of us, the actors trying to find the meaning of the scenes in which we find ourselves. The scripts are not yet fully written, so we must listen with curiosity and great care to the main characters who are, of course, the children. (Paley, 1986)

Maybe the reason I never learned much science in school is because it never seemed real to me. Actually, I saw science as either not real at all to me--like electromagnetism--or it was too real like blood-and-guts biology. So I always went to great lengths to avoid science. I had one year of science in high school (which I successfully put off until my senior year!) and one year in college. And I was proud of my avoidance because I felt strongly that science never seemed connected to anything else, and it was especially disconnected from me. Now as an adult I can think about science from political, ecological, and social perspectives but, because I consciously and actively avoided science throughout high school and college, I am missing a depth of knowledge that limits my use of these multiple perspectives. I am frustrated that science was never presented to me in ways that would have captured my interest or helped me see its usefulness. I just never understood its importance or worth to me or to our society as a whole. I am sorry now that I was so successful in my science avoidance.

Some key incidents for me related to science happened early in our first year together in the LISSS Project. These events finally gave me an entryway into science. I recall vividly a series of study group sessions in which Kathy Roth shared videotapes of her fifth-grade science teaching and examples of written work and interviews from Marcus, a student who was typically not successful academically. I recall anticipating that I would not have much to contribute to our discussion that day, although I was interested in what others would have to say.

As we examined Marcus' comments in class discussions and in his writing, I was surprised at how easily I was able to get tuned into his thinking about what "food" means in relation to plants. We examined how Marcus considered Kathy's (KR) definition of food as energy-containing matter, with water not being considered food by this definition. I was

impressed with how Marcus tried to use that definition to consider possible sources of food for plants in a class discussion:

Marcus: Brenda said you couldn't live without sun. Well, you couldn't live without water either. It doesn't mean it [sun] has energy.
KR: OK, you guys are doing some terrific thinking. He's arguing your point, Brenda, about the sun being energy. He's saying, say it again, Marcus...
Marcus: She said that you couldn't live without sun and that you couldn't live without wa-..., I mean...
KR: You couldn't live without...
Marcus: So I said you couldn't live without water either, and it's still not...
KR: So that doesn't mean that it necessarily has energy is what you're saying.
Marcus: Yes.

Later in the same discussion...

Marcus: I was thinking that , talking about energy, that maybe plants don't need it.
KR: That maybe plants don't need energy?
Marcus: Right.

And still later in the same conversation...

KR: And last comment, Marcus?
Marcus: I was thinking maybe you should try putting orange juice on them [the plants].
KR: I'm sorry, I didn't hear you, what?
Marcus: Try putting orange juice on them.
KR: Try putting orange juice on them, and why would you try putting orange juice on them?
Marcus: Because it has energy.
KR: Because orange juice contains energy. Orange juice does contain energy and is food for you.

As an English teacher, I was used to thinking with students about multiple interpretation of word meanings, but not in relationship to science content. Marcus's thinking was especially intriguing to me because he was not a successful learner in science, and I had always gravitated to kids who weren't learning. I was impressed with the way he pursued an idea, even if he wasn't sure whether his answer was correct. As I found myself caught up in Marcus's thinking, I realized two important things. First of all, I realized that I actually did have something to contribute to our group's thinking about science teaching and learning. I valued digging into children's ways of thinking and making sense of students' writing in writers' workshop. My interest and skills in analyzing student thinking could be helpful to the group in looking at Marcus's writing and talking about food for plants in science class. Secondly, I realized that just like Marcus could do some good scientific thinking and persist in constructing meaning, so could I. I became engaged in

wondering *with* Marcus about the meaning of food for plants. For me our study group focus on children's thinking and talking and writing was my hook into science.

This connection to science through students' thinking grew during the second year of our work together. In the process of planning to present our work at conferences, our study group developed different metaphors for ways of representing our thinking about teaching and learning. We built on Hermine Marshall's metaphor (1990) of classrooms as learning communities where thinking and sharing ideas is valued as much as producing products. We also developed a quilting metaphor that emphasized constructing connections within and across subject matter content. During these discussions I started seeing closer connections between what we were trying to do within and across different subject matter areas. In all subject areas, there were these important norms of interaction and attitudes toward knowledge that we were trying to nurture. For example, I learned that in science, students and teachers could construct knowledge together through discussion, debate, and use of evidence. These were norms I had never experienced in my own science learning, and yet Barb and I were actively trying to promote these kinds of norms in our writers' workshop. Together, Barb and I began to explore ways to bring learning of science and learning to write together. I began to see my area of literacy related to these ideas about the broader learning community that we all valued. Also, when I wrote a paper with Kathy Roth (Rosaen & Roth, in press) looking at the writing in science from both her perspective as a science teacher and from my perspective as a writing teacher, our analysis helped me see that science is one piece of subject matter around which we develop important relationships with students.

Through this learning community idea and our quilt metaphor, I can now connect with subject areas that are not *my* areas. But I could not initially connect with science and other subjects by starting with the subject matter first. Content that is less familiar to me was important but secondary. Now I frame questions about less familiar content differently. What is the content that we want kids to have ownership over? What content do we want students to develop good questions about? How can reading and writing support students in pursuing genuine questions

that matter to them? Getting into kids' thinking helped me see the power of children's thinking and helped me see that I, too, can think about and understand science with other teachers and students.

Looking back now over my personal history, I see myself as a product of sex stereotyping in science. Because I was unable to find science personally meaningful on my own I opted out of science early on, and no one challenged me on that. I was a strong student who was doing very well in all of my courses--including math and science. And yet it was OK for me to avoid science throughout high school until I finally took biology in my senior year and minimize that science classes I took in college. What if at least one teacher or advisor had challenged my rejection of science? What if I had been convinced (or required) to take more science courses? What if some of my teachers had provided learning experiences that were potential entryways into science? Marcus, a fifth-grade student, was a significant character in my new search for meaning in science. I only wish I had met him and a diverse set of characters who puzzled over interesting questions sooner.

Elaine's Story--History and Historical Inquiry as an Entryway Into Science

> Unfortunately, most readers first encounter history in school textbooks, and these omit the explanations and interpretations--the detective work, if you will. Textbooks, by their very nature, seek to summarize knowledge. They have little interest and less space for looking at how that knowledge was gained. Yet the challenge of doing history, not just reading it, is what attracts so many historians. Couldn't some of that challenge be communicated in a concrete way? (Davidson & Lytle, 1982, p. vi.)

I, too, was an avoider of science. It wasn't that I wasn't intrigued by the mystery, but I didn't do well. I took one science course in high school and then enrolled in chemistry. My father was a teacher in the school, and the science teacher asked him to take me out of chemistry after I caused an explosion in chemistry lab. I didn't mean to do it, but it was quite dangerous. I was just interested in mixing some things together that shouldn't have been mixed together. Anyway, that was the end of my relationship with science. I took one course in college and was done with science. When I started teaching six years ago, I knew I did not have the knowledge I needed to teach science. I was uncomfortable and insecure teaching science and had no one to help me with it. I became quite good at avoiding the teaching of science--I put every other subject first in my schedule, and this often did not leave any time for science. When I moved to fourth grade, a

colleague offered to teach the science for the fourth graders; fortunately, when I switched to fifth grade, a colleague again offered to teach the science if I would teach the social studies. This was an easy avoidance!

When I joined the LISSS Project, I didn't really think about the science part of our name. I joined the project with the intent of improving my social studies instruction. Since I was teaching social studies to three groups of fifth graders, I felt very responsible for teaching social studies well. I also liked social studies and the fifth-grade focus on American history and was eager to get new ideas about how to teach it better.

My interest in science was sparked during our first year together by listening to a third-grade science teacher talk about what she was doing in developing a unit about light and seeing and the phases of the moon that built on children's misconceptions. I admired her knowledge about the behavior of light and her ability to explain so easily the reasons for the phases of the moon. I also was stimulated by a series of study group discussions focused on brainstorming ideas about "naive" ways of thinking about light--both our own and those held by elementary children. We came up with so many examples of real world phenomena involved with light. It had not occurred to me before that ideas about the way light travels and reflects could be used to explain so many everyday occurrences. And we generated so many interesting questions! I admired the knowledge of the science-oriented members of our group and started to become intrigued with science, but I was still really focused on trying to get a grasp of how to change my social studies teaching. As we got into our readings and discussions about teaching for understanding, I found myself wanting to break away from my textbook-oriented curriculum for American history to a more conceptually focused curriculum. I didn't think I could make the kinds of changes I was just beginning to imagine in social studies and also take on science at the same time.

So I focused on my social studies teaching in that first year of our collaboration. As we read articles in study group, I grew increasingly frustrated with the short block of time, 30 minutes, that I had to teach social studies to each of three fifth-grade classes. I would just begin to get involved in a discussion with a class, and our time would run out. I was trying to introduce

student journal writing into my social studies classes. Originally, I had planned on giving students 5-10 minutes at the end of each class period to reflect on what had been discussed and learned. I found that even 10 minutes wasn't long enough. The students couldn't process and write fast enough to really make the writing worthwhile. I also found that we needed time to share what they had written. With our short time periods and 75 students, I wasn't able to get to know the students--and their thinking--very well. We would just begin a process of collaborating and thinking about some "big" issues in social studies, and then it would be time to switch. The 30-minute time block pushed me to feed my students with facts and information, and they would very obediently take it and move on from class to class. The 30-minute time constraint became more and more important to me as the year progressed. Going back to a self-contained classroom became appealing to me as a way to solve this problem. With support from Barb and the group, I finally made the change I knew I needed to make. I decided that in our second year I would take on the responsibility for science teaching and no longer switch classes for science and social studies.

The second year of the project was an exciting year of growth and challenge! I no longer had to contend with the time constraint of a 30-minute switch class. My time in the classroom was restructured to half time, which sounded really exciting--to be able to have two different work environments each day. I spent half days teaching fifth graders and half days learning with our university colleagues, reflecting and studying my practice, and planning curriculum, and teaching changes. We had also each decided to try out a teacher-researcher role, developing case studies from studying our teaching. It sounded important and impressive to be a teacher-researcher, but what did it mean? Aren't we as teachers always researching our teaching? How can we be more effective? What was this type of research going to be like? Would I be able to do it well? Would it be meaningful to me?

Fortunately, Kathy Peasley was interested in teaching science to my fifth graders during the fall of that second year. She wanted to try some new kinds of writing in science and to study the impact of that writing. This enabled me to watch teaching and learning in action. I always think of

myself as a visual learner, and I certainly learned a lot by observing Kathy's teaching and assisting in her research. Watching Kathy teach, I found myself getting new images of what it means to teach for "conceptual change." The articles we had been reading in study group were helpful and thought-provoking, but for me there was nothing like seeing it in action with my students. I was so fascinated watching how Kathy interacted with the kids; she had such a way with the fifth graders. And it was so exciting to hear what the fifth graders had to say--to hear them talking about their hypotheses and evidence. I was impressed at how scientific they sounded.

The two Kathys were starting the year in fifth-grade science (Kathy P. with my students and Kathy R. with Barb's students) with some ideas about scientific inquiry, and Corinna and I decided to do something parallel with historical inquiry in social studies. I used the ideas we discussed about scientific inquiry in the science planning group meetings (with Kathy and Kathy and Barb) in my social studies planning meetings with Corinna and Kathy R. The first chapter in the social studies text "covers" historical inquiry, but I had never paid much attention to it. It was a quick and easy chapter! But our co-planning in 1990 helped me turn that chapter into an extensive and intensive unit which involved the fifth graders in becoming historians. They did readings, conducted interviews, and wrote a history of Emerson Elementary School that we presented to the school library. It was exciting to me to think about history as being *constructed*, rather than just as a body of accumulated knowledge to be learned. I realized that my history knowledge had always been of the textbook type; I had never studied about or engaged in the actual process of doing history.

And then Corinna started co-teaching and co-planning with me on a regular basis, and my ideas about history and historical inquiry mushroomed--history as interpretation, perspectives, visible and invisible groups. The list goes on and on. Corinna had so much to offer me in helping me think about American history and social studies teaching! Corinna and I were co-planning and co-teaching social studies in ways I never before imagined possible. Our fifth graders were thinking deeply about issues like racism, discrimination, sexism, perspective, power, democracy, rights and responsibilities as they studied American history. As we were teaching the

fifth graders to become more critical readers of text, we encouraged them to ask questions about any text they read: Whose perspective is being represented? Whose perspective is missing? As Corinna and I engaged the students in becoming critical readers of history, I found myself becoming a more critical reader. I began looking for alternative interpretations rather than accepting the version as printed. History came alive for me as we began to include those ordinary peoples who are usually left out of history textbooks.

In addition to expanding my understanding of history and historical inquiry, I also became totally involved in examining students' thinking and in seeing how deeply fifth graders could think about these issues. I was surprised at how powerfully many students were able to connect these ideas with their own experiences with discrimination, sexism, and racism.

Meanwhile science was on the back burner and waiting for attention. Kathy Peasley was nearing the end of her time teaching in my classroom (to go off and have a baby!), and I knew I would have to take on science teaching BY MYSELF! I was definitely intrigued with Kathy's teaching--the kinds of ideas she got the kids thinking about. and the ways she encouraged them to question. I could see that she was more a facilitator than an all-knowing giver of knowledge, and that she was questioning and engaging in inquiry right along with the kids. But I was still frightened about my lack of content knowledge. I didn't feel ready to teach science. I remember sitting in on the planning meetings for fifth-grade science with Kathy Roth (KR) and Kathy Peasley (KP) and Barb. They would all get so carried away with ideas, and I would be sitting there not sure I even understood the ideas they were trying to help the fifth graders understand! Here is an excerpt from our conversation of 11/12/90, when we were discussing how I (EH) was going to start teaching after Kathy Peasley stopped. The conversation captures the tension I was feeling about teaching science:

EH: I don't know if I've got enough background knowledge to do this.
KP: It's, a lot of it is in the book [*Food for Plants* by Kathleen Roth, 1985]
EH: One thing about teaching a health unit is I feel fairly comfortable.
KR: You can do this. It's easy. It's, the basic concept, Elaine, is that the plant takes, it's just one basic idea. You're going to go over and over and over it in different ways. Basically, the plant takes in three things that it uses--air, water and sunlight. The sunlight has energy, the air and the water don't. This is how I explain it to the fifth graders. Somehow these three

things mix together and turn into food which has energy. Okay, so you've got the sun, the sun has the energy.

KP: It has energy but it has the wrong form of energy.

KR: Right, it has light energy.

EH: Oh gosh, you mean there's more than one type of energy?

KP: You can't eat light energy just like you can't eat electrical energy or heat energy when you're making chocolate chip cookies.

KR: Okay, so it has to have three things--the light energy, the water, and the air--those three things.

EH: Every plant has to have those to grow.

KR: Every green plant.

EH: Every green plant.

KR: It takes these three things and somehow in a way the plant does it that they're still studying , some amazing chemical reaction. These three things get turned into...

EH: Well, wait a minute. If a green plant needs that to grow, then why did the grass grow (in the dark)? It didn't grow green, but it grew.

KR: It is a green plant even though it is not green in color.

EH: Okay, I see.

KP: She's talking about the grass plant that was in the dark it wasn't green.

KR: Okay, then that's different. Here's the basic idea. This is photosynthesis. Light, air, and water, they get all mixed together in the cells and they make food in the form of sugar. That sugar, this tree can eat, that's what it lives on. If you only gave it water, it would not live. It has to have the energy that's sugar. So they eat this food that's made. The stuff it took in is not food.

EH: And it couldn't live with just the two of them? It couldn't live with just light and air?

KP: Right.

KR: It has to have all three. It has to eat inside of itself which is very different from people. What I tell the kids is you know, it's like if you're hungry you can't just go stand out in the sun and soak up the sun and drink some water and gulp some air and you're set. People can't do that, only green plants. Now, once it's made, this food it has, it makes more than it needs so it can store some.

EH: You expect fifth graders to understand this?

And the conversation continued, with Kathy and Kathy going on to answer more of my questions--talking about bean seeds and embryos and cotyledons and food storage. I was beginning to make some sense of it all, but I wasn't being totally honest when I ended the conversation by saying: "Okay, I can do this. Thanks, I feel better." I really didn't feel a whole lot better! This stuff did not seem alive like the history curriculum that we were creating. I felt like an outsider to this content--why were Kathy and Kathy so excited about all these details about how plants work? And as the year progressed, I found a good reason to allow my co-teacher (who teaches my students in the afternoon) to take over responsibility for science. I was intrigued but avoiding science again! I was still too focused on social studies to have the mental space to take on science.

Last fall--our third year together, I knew I had to be that science teacher. I again was hesitant, but I did it! I was ready to teach science, because I was feeling more comfortable with the social studies--I no longer had to revert to textbook-focused teaching when Corinna left me to go to a conference or to teach overseas! Fortunately, Constanza was eager to get in the classroom and do some teaching so she joined me often during science time. She provided critical support in co-planning and co-teaching science. As we taught together, I began to see many parallels between teaching science and the new ways that I had begun to teach history as inquiry. Just as I had learned to move away from right-wrong textbook-based "discussions" in social studies, now I was learning how science can be more than "getting the right answer." In science, too, people can have debates and present evidence to support different positions. Science, too, can come alive and result in lively classroom discussions. I remember a key turning point was a day that I kept an exciting discussion going in science for over an hour, and Constanza wasn't even there! At that point, science started becoming more comfortable, and it was exciting. I had so much wonderment and I wasn't afraid to share that with the fifth graders. We were all engaged in inquiry together. I remember the students' excitement when I gave them each a plant that was their own to study and care for. I was sorry I hadn't bought one for myself--I felt left out!

Right now I am not teaching science. Kathy Peasley and Constanza took over my science teaching this term so that I could participate as an instructor in the social studies methods class for prospective teachers. And now I am really focused on thinking deeply about social studies again. It has been a good break for me. I felt some success with science last fall, but it took a lot of my time and energy. It feels good to be able to put some time and energy into my social studies teaching again, knowing that my students are in excellent hands in science with Kathy and Constanza. As the winter term comes to a close, Barb and Carol and I have been meeting to plan a science unit about "deep time" that will involve both the third and fifth graders this spring. That is giving me the support I need to teach science again this spring and to explore a new science content area.

It's interesting how I now almost see myself as a better questioner and inquirer in science than in social studies. I have been really captivated by the conceptual change model, the wonderment, the questioning, the kids' ideas. It's easier for me to ask questions and not just give students answers in science. I have so much of a "history" of giving answers and looking for factual answers in social studies--I have to work harder there to break old habits. In science, those habits never formed (since I was so successful in avoiding both studying and teaching science). I'm as much a learner as the kids are. We're trying to find things out together and I like that. It's fun for me.

Barb's Story--Writer's Workshop as an Entryway Into Science

> A child's world is fresh and new and beautiful, full of wonder and excitement. It is our misfortune that for most of us that clear-eyed vision, that true instinct for what is beautiful and awe-inspiring, is dimmed and even lost before we reach adulthood. If I had influence with the good fairy who is supposed to preside over the christening of all children I should ask that her gift to each child in the world be a sense of wonder so indestructible that it would last throughout life. (Carson, 1956)
>
> Rachel Carson was equally a scientist and a writer. (Nature Company, 1990, epilogue)
>
> Through her books, Rachel Carson changed the way people look at the sea, then at the entire planet. (Wheeler, 1991, p. 1)

My focus early on in this professional development school effort was on professional development. What intrigued me about the PDS work was the opportunity to challenge long-held assumptions about teachers as technicians who carry out the recommendations of the experts from the university, from the research community, and from the school administration. The idea of restructuring our roles, schedules and responsibilities appealed to me. I believed that teachers had a lot more to offer each other and the larger educational system, and that we needed to break down the isolationism of classroom teaching, the low status of teaching, and the lack of professionalism in teaching.

So when we began negotiating the kinds of projects we might form in creating this PDS, I wasn't sure where to align myself. I had been active on the district's Communication Arts committee and was excited about the progress that group had made. It was one of the few opportunities I had had to collaborate with other professionals about curriculum. We were

studying the communication arts curriculum thoughtfully and reading literature to help us make recommendations for change. It felt good to have my ideas valued in this group. So as projects formed in our PDS effort, I thought about whether I should continue my focus on literacy issues or go in a new direction since I had already been doing a lot of thinking about language arts. For example, I considered joining the math study group because I felt like that was my weakest area. But in the end I went with my area of strength. For despite all my work in language arts and despite being the teacher responsible for teaching "English" to the three fifth-grade groups, I still knew that I hadn't "arrived" in my language arts teaching. A main reason for deciding to stick with a language arts focus was because I had done a lot of thinking about that area, and I had a lot of ideas but I knew it wasn't right yet. I had invested a lot of time but there was still something missing.

I was not thinking about science at all when we started this project. It wasn't that I didn't like science. My second major in college was in earth science. But I didn't like all *kinds* of science, and I hadn't taught science in a long time. When I taught at the middle school, the science curriculum was very activity-oriented, and it frustrated me. I didn't like doing one activity after another--it was very messy with moldy bread, dirt, and chemicals everywhere. I didn't enjoy teaching science that way, and I couldn't imagine teaching science any other way. That's just how science is supposed to be taught.

During the first year in our LISSS group instead of thinking about science, I was focused on seriously rethinking how I teach writing. I was so intrigued with the idea of process writing, but I couldn't get a handle on how to put it into action. And I wasn't sure what to do with my traditional grammar approach to teaching writing. Thinking about writing instruction really absorbed me that first year. I only thought about science and social studies in terms of writing. For example, I thought I could support the students in doing some interesting writing based on their learning in science and social studies. Early on I tried to connect some of our writing assignments with what students were studying in science. Another fifth-grade teacher was teaching science to my students at that time. I talked to her about a writing assignment related to

the current topic of study in science--vertebrates. She encouraged me to try it. I tried it and felt like a failure. I had assumed that the children would come to me from science class with all the content knowledge and that I would just help with the writing. But I found myself involved in discussions with the kids about the content--about vertebrates. I was so unsure of the content and felt uncomfortable when questions would come up. I felt like I needed to do a lot of studying up on the content before I could help students write about this content. So I dropped the writing in science idea as soon as that assignment was finished. But I continued to puzzle about my realization that I had to be both a writing teacher and a science teacher to help students write about science.

Like Elaine and Carol, I chose to take on responsibility for teaching science in our second year. I wanted to be more self-contained in order to have more control over my instructional time. I needed larger blocks of time to get a writers' workshop approach started in my classroom. Thirty-minute time block limitations were not compatible with getting such a writers' workshop going! I knew that just the idea of starting a writers' workshop approach was going to be a big step for me and would take a lot of time and energy. So I was hesitant about taking on a second new project--science. But Kathy Roth was eager to do some fifth-grade science teaching in my classroom in the fall, and I had a student teacher coming in during winter term, so I felt pretty comfortable taking it on. I planned to do some kind of earth science unit, my area of strength, in the spring when I would be the primary science teacher.

I began to become more interested in science when Kathy came into my classroom and started teaching science in a very different way than I was used to. Although she had the kids doing activities (and yes, she did have a lot of junk cluttering up my classroom!), it was not just one activity after another. The big difference I saw was the connectedness of the activities and the discussions over time. She and the students were engaged in an ongoing inquiry together. I was fascinated. I had never thought about teaching science from such an inquiry perspective. I was also intrigued with the students' thinking. As an observer and support person for Kathy's research on her teaching, I had the luxury to watch the students. In fact, I really watched them a lot more

than I watched Kathy. I had always been frustrated that kids were not thinking in school. I had wonderful goals of engaging students in thinking but I didn't know how to do it. In my English classes, it had been impossible for me to see how to get thinking going when the text just guided us through one set of exercises to another--I would explain, the students would do the exercise, I would explain, the students would do the exercise in a predictable cycle. The thing that frustrated me the most about teaching was I knew there wasn't any thinking going on in my classroom. The kids just did stuff and I was like the manager, making things happen.

While I was watching Kathy teach science, I was also co-planning and co-teaching writers' workshop with Cheryl. Cheryl was helping me think about ways to help children to take more ownership over their writing, to get more involved in their writing projects. I noticed that I was hearing a lot more of my students' voices in writing class also. As I continued to focus on my writing instruction and to watch Kathy's science teaching, I got more and more excited about the connections I saw between what Kathy was doing in science and what Cheryl and I were trying to do in writers' workshop. Kathy had students writing in science, and she encouraged them to take ownership of the ideas in science, to reflect back on their writing, to revise their thinking and their writing, to use written records of their thinking to track and evaluate their own growth. She was helping students think and take more responsibility for their own learning.

Another parallel I saw was how she respected the fifth graders and listened thoughtfully to their ideas (rather than quickly assessing them as right or wrong). She tried to use the students' ideas in productive ways, and her planning was responsive to their thinking. Although she was using a text (that she had written), she seemed to use the students' thinking to guide instruction more than the text. I saw so many parallels in writers' workshop. In teaching writing, Cheryl and I were using the students' writing as the texts for our class, not the grammar book. We were respecting students' ideas and writing, and it was paying off in increased engagement and less need for any kinds of disciplinary actions. Kathy was treating the students as scientists, and we were treating the students as writers. And I began to see how the way you ask questions and how

you listen to children matches with what you get from them. Making those connections between science and writing was a real awakening.

This year I have been very interested in my science teaching. I have felt comfortable teaching it on my own, with planning support from Kathy Peasley and others. Right now Carol and Elaine and I are planning an inquiry-oriented unit that we refer to as our "deep time" unit. The focus will be on the nature of scientific inquiry, geologic time, and natural history writing. We will study what is known and unknown about the history of earth, and each child will be challenged to identify a question about the earth long ago that s/he wants to study and wonder about. The unit will integrate science, social studies, and writing as students consider how scientists, historians, and writers study and write about the history of the earth. The idea for the unit came from the students' requests to study about dinosaurs and from my earth science background. Like Carol, I have become a bookhound on this topic. I have enjoyed reading books by Stephen Jay Gould (1991) as well as Robert Bakker (1986), John Horner and James Gorman (1988), Don Lessem (1992), Stephen Hawkings (1988), and Rachel Carson (1956). These writers are enabling me to explore science in much richer ways than any science textbook could. As I read, I get caught up in the scientists' passions and patience in wanting to know and understand the world. I think about ways to help communicate these aspects of science to my fifth grade students.

In becoming comfortable with teaching science, it has been important for me to have some curricular freedom to teach science topics that interest me and that draw on my subject area strengths. In the past, I felt threatened by the fifth-grade science curriculum--especially the physical science parts like electricity. The book never felt right to me, but now I am able to see what it was missing. In an attempt to cover a little bit of this and a little bit of that from each of the areas of science, there is little connectedness. Science to the children is embodied in a series of isolated units. One thing that has been exciting for me in thinking about science is how connected it all is. When I taught about the history of life on earth last spring, I found that I could connect this content in interesting ways with earlier units we had studied about adaptations,

photosynthesis, the human body systems, and cell respiration. The students got intrigued with questions about the first one-celled plants, about the evolution of plants and the atmosphere, and about the insides of dinosaurs: Did they have cells and digestive and respiratory systems pretty similar to ours?

When Kathy was teaching science in my room last year, I found myself frequently asking her: How can a regular elementary teacher responsible for all subjects do this kind of teaching? How can they have the knowledge about science? How can they follow student thinking that closely? After all, I had significant restructured time to study these issues, and I was still overwhelmed, overworked. Reading and discussing Hermine Marshall's article (1990) in which she contrasted classrooms that are work-oriented with classrooms that are learning-focused was a key turning point for me. An elementary teacher responsible for teaching all subjects cannot possibly be an expert in everything, but this view of learning together emphasizes that the teacher has many other, important roles besides that of expert and authority. What a relief! Now I get excited when a student asks a questions I cannot answer, or when a student challenges my scientific explanations. Instead of feeling like my authority is being challenged, I am excited that the students are thinking!

Being involved in the study of our students' learning about science last year has helped me understand how hard, hard, hard it is for students to change their thinking. I am now much more patient with both them and myself as learners. Returning to my original goal of wanting to try a new form of professional development, I see our interactions in the LISSS group as standing in stark contrast with traditional inservice workshops and "training" sessions. I am now aware of how hard, hard, hard it is for teachers to teach for understanding in all subject areas and for teachers to change their practice. Like students, we need ongoing support over time and we need time to think and reflect about our experiences. We need conditions that will enable our sense of wonder and inquiry about teaching and learning to last throughout life.

## The Second Theme: Multiple Perspectives Contribute to Science Educators' Professional Development

### Kathy Peasley's Story--From Science Belonging to the Elite to Science Ownership for All

> Science teaching today too often contributes to the "mystique" of science...a set of harmful myths that favor the interests of a small elite...Science teaching often succeeds only too well in convincing students that science is inherently so much more complex and difficult than other subjects that most students will never really understand science. As more and more decisions that affect us all involve scientific and technical issues, this attitude encourages us to defer to what managers tell us "the experts" say we have to do. (Lemke, 1990, p. 129)

> The traditional view of science represents a distorted understanding of science that needs to be exposed in school science as a mythology. Science, like other disciplines, is a product of its history, with no special claim to an elite status. Scientific reasoning is a competence that everyone can achieve. One need not be a part of an elite group or hold its values to be able to understand science. (Brickhouse, in press)

When we first began this project I was particularly interested in looking at the role of writing in science. However, I started with a very superficial understanding about the purpose of writing in the content area; I was primarily thinking about integrating some "fun" kinds of writing activities into science as a way to improve the writing process.

A key reading in broadening my thinking that first year was the Langer and Applebee article (1987) that Cheryl shared with us. Langer and Applebee had done a study looking at secondary teachers' and students' perceptions of the purpose of writing in various content areas. I remember that every study group for what seemed like months Cheryl would write Langer and Applebee's functions, or purposes, of writing on the board and would use these functions to organize our discussion at different times. It was good that she did this, because it took a long time for these functions to become meaningful for me. They were a very different way of thinking about the role of writing in learning subject matter, and yet they eventually became very important in helping me think about organizing the science curriculum in different ways.

As we got into discussions that were focused directly on writing, Cheryl kept bringing up the idea of genuine or authentic writing. In this context the question of ownership in students' writing also kept coming up. Although these discussions around ownership and authenticity were primarily in the context of creative writing, I kept connecting the terms "authentic," "genuine," and

particularly "ownership" with the idea of social construction of knowledge in science, which was an area in which I had become very interested through my coursework in the doctoral program. Everything that Cheryl was talking about in terms of writing connected closely to the ideas I was trying to sort out with respect to the social construction of science knowledge. In particular, these issues discussed in the context of writing got me thinking beyond just the writing in science to thinking more deeply about the *content* of science. How could this content be more real for my students? How could it be about their questions instead of mine? How could I help students to develop more ownership of science knowledge?

The ownership issue, initially introduced in the context of writing instruction, became an important thread for me in all aspects of our project work. It was the idea of ownership which challenged me to reconsider what I meant by my goal of "science for all." How can science be part of *all* students' learning and experience?

When I taught science in Elaine's fifth-grade class in the Fall of 1990 I had a very different definition of science than I do today. At that time I was very proud of being a "science person." Science--the way I was taught--did not come easily for me; it was in many ways counter to the way in which I thought and learned. Therefore I had a notion that the *discipline* of science, like school science as I knew it, was something difficult, something accessible to only those who worked hard, and met the challenge, as I felt I had done. I was especially proud to be a female who had "made it" in science, and was even more proud that I had worked in a "real" science laboratory for a short period, and could thus serve as a role model for other females to pursue a career in science. I had the notion that I was going to help my students by somehow raising them all up to this elite level. Science could be for all students if I could help all students reach this elite level.

As the study group has supported me in examining the richness of students' thinking and in pushing the idea of student ownership of knowledge and what it means to genuinely construct knowledge for oneself, I have moved to a different vision of "science for all." I no longer see myself as somehow above others because I am a member of an elite science community. Rather I

am concerned about ways in which science teaching so often perpetuates this elitist image of science in which the authority for science knowledge rests in a few individuals at the top of the hierarchy. It dismisses too easily many students' (and adults') access to and contributions to the scientific community.

As I am co-planning and co-teaching the fifth grade with Constanza this year (again in Elaine's classroom), I keep thinking about the ideas that we have developed in our project about the creation of learning communities in our classroom and about this notion of student ownership of knowledge. I keep coming back to the question of who owns scientific knowledge. And who has the authority for determining what scientific knowledge will be constructed in an elementary science classroom?

Therefore, the thread of our work that focused around writing has had a dramatic impact on my thinking in science. More recently, social studies is also starting to challenge my thinking about the kinds of science knowledge that will be meaningful and challenging to fifth graders. As I watch the social studies teaching that a student teacher is doing in Barb's classroom (in my role as her university instructor) and as I learn more about social studies in Elaine and Corinna's classroom, I am fascinated by the teachers' willingness and effectiveness in exploring substantial issues like racism and perspective with fifth graders. Such explorations have pushed me to think more deeply about the importance of science concepts. What science concepts will push students' thinking in deep versus superficial ways? Which science concepts have I assumed were too complex and difficult for fifth graders that I should reconsider? Are there social aspects of science that fifth graders could understand in deeper ways? Thus the work in social studies is challenging my assumptions about the kinds of science ideas that fifth graders can study in meaningful, productive ways. It is also challenging me to consider more controversial aspects of science that might be appropriate in a fifth grade science curriculum.

I started with a notion that as a teacher I wanted to lift my students up into an elite scientific community. It was as if the scientific knowledge was located on high mountain peak, and I had to help push, support, encourage my students to climb up a steep, tortuous, dangerous path to get the

knowledge. If I could just keep all the students going, they would eventually all reach the pinnacle. Now I have more of an image that the science knowledge is everywhere--on the mountain peaks, in the valleys, in the woods, in the plains, in the oceans, and in each of us. Instead of an image of the teacher pushing each student individually up the ladder to claim knowledge, I know imagine myself as the leader of a group of explorers. As we explore together a new area of our world, we draw from the past experiences and knowledge of each of us. I have been to the mountain peaks and know much about the scientific knowledge there, but the students have been many places, too, and their knowledge helps us all construct together better understandings of the world we are exploring together. In this view of science and science teaching, the students are not outsiders looking for the way up the mountain peak to claim the treasure of knowledge. Instead, all students can find meaning in science by exploring the treasures of knowledge that can be created by looking within and around themselves--and the valleys can be just as exciting, productive, and beautiful as the mountain tops.

Kathy Roth's Story--From Teaching Science to All Students Equally to Teaching Science Equitably

The Learning Gate

Do you like what you see
Every time you look at me?
My full lips
Broad nose
Smooth ebony skin
crinkly hair
My smile within?
My name may be
Aykram
or
Imam
or
Nia, Taxia
Nefertiti
or
Hassan
But whatever my name
and the history it brings
How will you teach me
If you don't learn the
rhythms I sing?
(Cornwall, 1988, p. xiii)

> Who are these people who would do science if they could? They are Blacks and Hispanics and American Indians, girls and young women of all races and disabled students of both sexes and all races. The great irony is that as bad as the educational system may be overall, its failure is most dismal precisely for members of these groups. (Malcolm, 1990, p. 112)

Valuing students' differences. When we first started this project, I was relieved that I had found a place at Emerson where I could pursue my interests in science teaching. In our long negotiations about areas of interests, I kept wondering, "Where is there going to be a place for me? No one is interested in science." I recognized that the science in our title was the result of my persistence and did not reflect the interests of the Emerson-based educators in our group. I naively assumed, however, that everyone would get intrigued with science when I started sharing with them my video and written materials illustrating my efforts to teach science in new ways. I had recently conducted extensive research on my teaching of science and social studies to fifth graders in an urban school nearby, and I was excited about what I had learned from that study. In that teaching effort, I examined how my teaching practice would be influenced by my research experience (Anderson & Roth, 1989; Roth, Smith, & Anderson, 1983) and by a larger body of research that described student thinking and learning in ways that provided new insights into why students have difficulty learning science (Anderson & Smith, 1983; Champagne, Klopfer, & Anderson, 1980; Clement, 1982; Driver, Guesne, & Tiberghien, 1985; Erickson, 1979; Gilbert & Watts, 1983; Johnson & Wellman, 1982; Novick & Nussbaum, 1981; Nussbaum, 1979; Nussbaum & Novak, 1976; Osborne & Freyberg, 1985; Stead & Osborne, 1980; Trowbridge & McDermott, 1980).

As I took insights from this research into my teaching experience, I saw that it enabled me to make dramatic changes in the way I approached students and their learning. I was fascinated by the ways in which my teaching was reshaped as I strove to really listen to and understand children's thinking in new ways. It was exciting to see how getting in touch with children's thinking enabled me to make instructional plans that were responsive to where the students were and to see strengths in students who I previously would have assessed as average to below average. By the end of the year, these students were all in different places in their understandings

of science and science concepts we had studied, but each had made significant growth. As a teacher, I had a much better sense of what students had *learned* (versus what I had *taught*) than I had ever experienced before. These fifth graders were able to use scientific knowledge in ways that I had not seen in my previous middle school students or in research studies that I had conducted with other fifth graders in more privileged schools. I was excited about what I was learning about the possibilities of really making a difference in all students' learning in science. I was eager to share this excitement about students' science learning with my professional development school colleagues.

Early on in our first year I showed the LISSS group a videotape of one of these fifth-grade science students being interviewed about human body systems. The LISSS participants were planning to interview Emerson children, and I thought it would be helpful to look at an example of an interview. I was surprised and disappointed with the general lack of engagement with the content of the interview. It was clear that many participants were not really trying to follow the student's line of thinking about the human body systems and cell respiration. I felt taken aback when someone asked whether this was a "star" student. An issue of great concern to me was making science accessible to *all* students--not just the "star" students. In fact, I realized at that moment that I no longer think about star students. I had come to view all my students as "stars" in very different, individual ways. It was clear that others in the LISSS group were not intrigued with this "star" student's thinking about the human body, and I worried that some of the participants thought I was trying to "show off." After that experience, I consciously worked not to push my interests and excitement about science teaching and learning on the group as much. I wondered what my purpose was in the group if I could not contribute my science expertise. I looked for opportunities to support others in their science planning needs.

In the second year I was shocked and delighted when all three of the teachers in our group decided to teach science. Because of their lack of interest in science, I had assumed they would continue to avoid it. Their decision gave me an important way in which I could contribute in the group. I negotiated to teach science for Barb in the fall, while she focused her efforts on

establishing a writers' workshop and on conducting an inquiry with me regarding the students' learning in science. Now I had found a way to contribute my science interest and expertise to the group.

But I was still viewing this path of expertise as one way--from me to the science avoiders in the group. What was so exciting in that second year and continuing into the third year were the ways I changed my thinking about science and about science teaching and learning as a result of my interactions with the nonscience members of the group. While I was opening doors to science for them, they were helping me view science from the outside and opening up windows into science teaching that I had never opened before.

Discomfort with students' differences. Emerson Professional Development School is located in a predominantly white, blue-collar community adjacent to the much more ethnically diverse city of Jarvis. The community has rural roots but has grown to include a large working-class population. More recently, the community is growing as a suburb of Jarvis to include some professional families. Of the 22 students in Barb's classroom, only two had parents who had completed four-year college degrees. Emerson is not a school identified by educators as a place to study equity and diversity issues, since its student population is typically seen as quite homogenous. However, some of my earliest impressions from discussions with teachers in the school was that this was a school filled with at-risk children. Seventeen percent of the students, for example, come from families living at the poverty level. Teachers at Emerson and across the district view this school as the elementary school in the district having the most at-risk children, perhaps because it served a low-income trailer park nearby. I heard many stories about these at-risk children--stories about kids setting dogs on fire, promiscuous young girls, kids coming to school dirty, abusive parents, "broken" homes, kids "growing up as weeds"--untended and cared for.

An early critical incident was my experience interviewing one of these "at-risk" children. Bob had been identified as a student from a broken home, a student who often came to school dirty, a student who was totally disconnected from the academic life of the classroom. As part of

our research, I interviewed Bob, a fifth grader, about what he had been studying in social studies. Bob surprised me by having a great deal to say about early colonization in the United States and about the events of the Revolutionary War. He described a treasure trove of facts and details that had been discussed in class. He described these facts and stories to me with great enthusiasm and cooperation and in a quite coherent story line.

During the interview, I also learned about his family life--about his travels to visit a brother living in Tennessee and also about a family member who was involved in Civil War reenactments as a hobby. Here was a student who had a great deal to contribute to the class, but who instead had been largely written off as a school failure. His home life as well as his academic life in school had a richness that we had not recognized. Our study group watched the videotape of the interview in amazement; it was an eye-opening experience for all of us. I used this incident to encourage others to adopt my goal of looking beyond what I viewed at the time as "external" differences and family problems to focus instead on what these students are capable of learning and understanding. It was a striking case to challenge the usefulness of labeling all these children as "at risk," when such labels could so often be misleading and serve primarily as a way of writing certain kids off, of making excuses for why they do not do well on standardized tests or why they do not get engaged in classroom activities.

As I look back on this experience, I see that the case of Bob and other students like him enabled me to support and push *my* agenda in the LISSS group--to convince others to overlook family and socioeconomic differences in order to see, celebrate, value, and build on students' differences in terms of knowledge and experience academically. But Bob's case did not push *me* to challenge my uneasiness with dealing with differences other than academic--with social class differences, racial differences, economic differences, gender differences, and so on. These I just ignored and saw as irrelevant to teaching science. I could think about learners as individuals in terms of how they thought about science concepts, but I did not want to see their other differences. I tried to respect each child's ideas, contributions, and potential. But if I noticed students as boys

or girls, as black or white, as rich or poor, I feared I might treat some students preferentially. I wanted to treat all students "equally." I thought I needed to strive to be color blind.

Developing new lenses for looking at diversity and equity issues in the science classroom: Color vision. It was through my interactions with the "social studies people" in our group that I gradually started thinking differently about race, social class, gender, and equity issues in science and science teaching. These ideas were closely linked to my unfolding understanding of the idea of classroom learning communities. I knew it was important to me that all students be part of the science classroom learning community, that all students feel safe as learners who can change their thinking publicly without fear of being labeled stupid or slow. I gradually came to understand that race, class, and gender differences might play a role in determining how safe a student felt to be a contributing member of our science learning community. Through discussions about the social studies case studies that Elaine and Corinna were developing, through collaborative planning of both fifth-grade social studies and a social studies methods class for prospective teachers, and through Constanza's research on gender and race issues in my fifth-grade science classroom, I began to rethink these issues.

For example, with Constanza's help, I began to study and understand differences in communication patterns among girls and boys in my science classroom. I saw how small-group discussions that at one level appeared very productive to me as the teacher may have at another level silenced the girls and other traditional outsiders to science. Constanza noted a pattern of discourse in which the girls had less voice and salience despite holding valuable insights and understandings about the content. If I treated the boys and the girls equally, this pattern would continue, and it might contribute to girls learning that they are not good at science or that science is about being loud and fast in getting your ideas on the table.

And then there was Laticia. Only in hindsight was I able to see the special challenges she faced in joining our science learning community not only as a new student in October but also as the only African-American student in the class. If from the beginning I had recognized and empathized with the feelings of Laticia as she negotiated her role as a new student in an all-white

classroom, I could have better understood the conflicts and pains she encountered--pains that were different from experiences of new white students in this classroom, pains that would affect her willingness to share ideas in science class. I look back and regret that I did not have these insights when Laticia entered our classroom. I treated her "just like everyone else" when I now believe it would have been more equitable to give her some special kinds of support. When she joined our class, I tried hard not to notice that she was "different." I wanted to treat her just like everyone else. But looking back, I see the special challenges that Laticia faced in sharing her science ideas both in the small-group and in the large-group settings. And I should have been prepared to give her special support. I could have done more to tap her knowledge and experience. In fact, it was some special support that eventually enabled me to connect with Laticia and bring her into the center of our learning community--but that support came only in a time of crisis when Laticia lost her temper as a result of the isolation and hostility she felt from girls in her group.

In another case, Elaine and Corinna's teaching and research made Maria-Yolanda visible to me as a Mexican American for whom race and discrimination were very salient issues. In seeing all my students as equal, I did not genuinely acknowledge Maria-Yolanda as a student of difference. Like the fifth graders in the class, I guess I just saw her as a student with "a suntan that never goes away." If I had been more sensitive to the possibilities that her racial difference might be important to her, perhaps she would not have remained such an invisible student in my classroom. Just as the interview with Bob and his articulate connection to academic content had been a critical incident for his teachers, so Constanza's (I) interview with Maria-Yolanda (MY) was a critical incident for me.

Maria-Yolanda was extremely quiet in science class, and when she did speak to me privately or in her journal I had not been impressed with the quality of her thinking. Her other teachers commented on a similar apparent lack of engagement in academic learning. I remember when Elaine and Corinna chose her to be one of the students interviewed in social studies that I was glad I was not interviewing her for science. And yet as I watched the videotape of social studies interviews with her, she was heartbreakingly articulate in talking about her racial

experiences and her understandings of social studies concepts about discrimination and invisibility in history. In the following excerpts from her interviews Maria-Yolanda reports her personal experiences with discrimination and then connects discrimination to invisibility, saying that race has a lot to do with why certain groups are invisible in history:

I: Do you see other social conflicts at school besides the boy and girl conflict?
MY: Not really. Well, name calling. Like that's a social conflict because that's not right. There's two people arguing or more.
I: Can you give me an example?
MY: I got one. You know when you came in to talk about Texas and how you grew up? Well, Gary had said, "Well you are just Mexican burritos" and then Ms. Hasbach stopped him and started talking about it. I turned around and I said, "That's not right Gary" and then see we were going back and forth and then Ms. Hasbach said, "Wait a minute. I just heard something that I didn't like." So that was something that was a social conflict.
I: How did you feel about Ms. Hasbach saying something?
MY: Well I felt good because not every teacher will stop and say something if somebody had started discriminating against you because of your race.

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I: Some groups have been invisible in history. First, let's think about the word invisible. What does that mean?
M-Y: They weren't like nobody really paid attention to them. They discriminated against them and I know the groups. The colored, the Hispanics, and the Mexican Americans. Those people were very invisible because they didn't have their rights and they were discriminated against.

This very quiet student was even seen as invisible in the classroom by her best friend, Sara (S):

I: What do you think being visible means?
S: Visible? Like white Americans are visible because they have all the power and that you could see them [inaudible] and their ideas counted and that whatever they had to say, it was usually important because they have power and they weren't invisible.
I: Okay. Now, in your social studies class, do you think that there's anybody in there that you would consider invisible?
S: No, because everybody should be treated equally. Some people don't, like, they just sit there really quiet. Like my friend, Maria-Yolanda, I really like her a whole lot but, she doesn't ... she just sits there quiet, she's not visible for her ideas to count, but she doesn't really say a whole lot.

And yet in an interview, Maria-Yolanda explains how her experiences are different from those of her classmates and boldly proposes that she share her special understandings of racism by making a speech to the whole school about discrimination:

MY: I would understand how the Mexican Americans and the Hispanics used to feel. This is something I think, I don't think a lot of people in there cared because they don't know what it feels like to be Hispanic and discriminated against. And they don't even know what colored people feel like. I don't think they really cared. I don't think a lot of white people got discriminated against besides the women.

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MY: I would say something [to the school] like people are out there discriminating against people's race because they're different than you but nobody is different because they all have the same feelings. Just because their pigment is different there's nothing wrong with them, they're still human.

But Maria-Yolanda's comments about the journal writing in social studies and about the power of language were the most poignant for me. They helped me identify the opportunities I had missed in helping Maria-Yolanda find science meaningful:

MY: They have those journals, so we could write how we feel. She told us these journals are for how you feel and I've wrote in it a couple times about how I feel about being called a Mexican burrito.

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MY: [Social studies] helped me because I always thought that, not to be rude or anything, but that white people always discriminated against my colored friends and that's what we talked about. Other colors discriminating against other races, and it was like, "Oh I know that."
I: So you knew all that before?
MY: Yes. Well not the words but I just knew that people were rude because they say "Hey, you N [reference is to "nigger"] word.
I: Now you said, "I didn't know the words," what words?
MY: Well like "discriminated," I didn't know those words. I just thought people were rude so used to use that term rude.
I: And why is it important to learn these terms?
MY: I don't know, I think they are more grown-up words. Like you know, those older people use those terms, "discriminated."

At the beginning of the year in science, Maria-Yolanda had attempted to use her science journal in a personal way that went beyond what was required of the class. She privately showed me how she had written in her journal about experiences at home, and she was clearly taking seriously the idea that the journal could be a dialogue with the teacher. At the time, I was impressed with this effort but I did not perceive it as a critical moment in my relationship with Maria-Yolanda. After all, the writing she had done had very little to do with science. It seemed like a nice *personal* moment of connection between Maria-Yolanda and myself, but I did not see it as a way to help Maria-Yolanda connect with *science*. Now as I look back on her consistent silence and disconnection in science class, I realize that I should have encouraged this unintended use of the science journal. By being responsive to nonscience content in the journal, I may have

been able to find ways to help Maria-Yolanda connect the issues that were important to her to our work in science class.

But I didn't know until the year was over about Maria-Yolanda's experiences with discrimination and her passionate feelings about this discrimination. A journal dialogue with her could have helped me know about her concerns, and might have enabled me to find ways to connect our discussions about scientific inquiry and about species and the history of life on earth with her concerns about human interactions and racism. Perhaps her interests could have challenged me to pursue further and more deeply the idea of stereotypes of scientists that I had introduced. Perhaps I could have opened up a critical examination of the way science has been constructed historically and pointed out issues of invisibility in science, ideas that may have challenged students like Maria-Yolanda to make themselves more visible in science.

As I noticed and started to understand more deeply the multiple kinds of differences that my students experienced, I began to see ways that I might be able to support the girls and the boys, the students of color and the white students in ways that were different but perhaps more equitable. Treating them differently to help them learn how to communicate effectively with each other was not treating them equally, but I felt was a more equitable instructional decision. I wanted to help girls, for example, learn how to gain and hold the floor in a conversation.

I have the same kinds of regrets and hopes for students like Maria-Yolanda and Laticia. Their stories have pushed me to rethink what it means to be a member of the scientific community. These students and the social studies members of our group have challenged me to read anew the history of science and to view science as a social construction that is not immutable. Our current definition of science was constructed by a limited subset of humans, primarily white Western males. How might the definition of science become broader and richer if it is redefined by humans--like Maria-Yolanda and Laticia--bringing different experiences, perspectives, voices, histories, and ideas about ways of understanding our world? How can traditional outsiders to science not merely become "members of the club" by adopting white, Western, male behaviors and values but actually change the nature of scientific inquiry in ways that would benefit us all? How

can science teachers encourage and prepare all students to not only understand and appreciate science concepts but also to understand the scientific enterprise--to appreciate and value its power to enrich our lives and to critique its unquestioned assumptions and its ways of silencing voices of outsiders? Might a more human and critical study of science--and all its uncertainties--resonate with students who have traditionally felt excluded and alienated from science?

These are the kinds of questions that I am now asking about science, about science teaching, and about the students in our science classrooms. I can no longer look at the outsiders in my classroom as "just the same" as everyone else. They bring special histories and experiences that may mean they need different kinds of support in learning science. I recognize the danger here of being perceived as advocating a less challenging curriculum for some students. In fact, I am arguing all students can benefit from a much more challenging and perhaps controversial science curriculum than they currently experience. I need to explore ways of clarifying my new position and communicating this position to others so I clearly send that message that all students are capable of understanding science in meaningful and complex ways, but that it will take very careful planning and teaching to find ways to help all different kinds of students connect with and develop personally meaningful scientific ways of knowing.

Constanza's Story--From Science as Outside Ourselves to Science as Socially Constructed

> We are beginning to see the biosphere not only as a continual struggle favoring the most vicious organisms but also as an endless dance of diversifying forms, where partners triumph. (Margulis & Sagan, cited in Barlow, 1991, p. 45).
>
> Who are these people who would do science is they could? They are Blacks and Hispanics and American Indians, girls and young women of all races and disabled students of both sexes and all races. (Malcolm, 1990, p. 112)

I have to begin my story by going back eight years when I was teaching students in Bogota, Colombia, my native home. I was recruited to the school as a specialist in science who had a strong background in biology. I thought I knew my subject matter pretty well and that I could become a good teacher through practice. I wasn't minimizing the importance of my lack of pedagogical knowledge. I just assumed, like many teachers, that I could learn most effectively about teaching strategies through practice. I taught science using a process approach, and I was

really into it. I was sure the students were learning! Just recently, however, two of my former students visited me here in Michigan and forced me to acknowledge that my assumption about their learning was wrong.

In my science teaching back then, I was using the Houghton-Mifflin elementary science textbook (Berger, Berkheimer, Lewis, & Neuberger, 1979), and I came to Michigan State University to meet one of the text's authors, Glenn Berkheimer, to learn all I could about how this textbook was written. How was it put together? Where do the ideas come from? At the time I started my doctoral program, I was still looking at science knowledge and scientists as experts "out there." The science education faculty at MSU, including Berkheimer, were the science experts with all the answers to my questions.

You don't see much beyond science when you're in a science career. You really don't question much where science came from or think about how it is socially constructed knowledge. But these were ideas and questions that were stimulated in the LISSS group and in my doctoral studies. In my role as researcher, I watched and studied fifth-grade instruction in science, writing, and social studies. Long conversations followed during study group and beyond about social construction of knowledge and the role of race, class, and gender in that process. I remember many times lingering in the parking lot to debrief with Corinna about her co-teaching of social studies and about my observations of science and writing workshop.

When I joined the LISSS Project I saw my role as a science resource person, a science expert. I remember one study group meeting that was critical for me in that first year. We were helping a third-grade teacher think about her planning of a science unit about light and seeing. In the session, we talked about how light travels and how it enables us to see. A goal was to brainstorm ideas about how students might think about light and what difficulties they might have in understanding the scientific conceptions. Unlike my former students, the nonscience members of the LISSS group kept pushing for clarification and asking questions. They were not satisfied with "textbook" answers! Their questions were great--they forced me to rethink what I "knew" and to redefine things I had always taken for granted: How come I find myself needing more light

to read as I get older? What is the relationship between sunlight and light from a lamp? How do scientists know that light travels in straight lines? Would shadows be reversed in the southern hemisphere? I had never created this kind of environment in my classroom--my students never asked these tough questions which would have been evidence of their attempts to really make sense.

I also remember in that first year working as a resource person with Carol in her planning of the prehistoric people unit; I realized she did not know she was teaching science in this unit. Was it important for her to know that she was teaching science? I wondered if it would feel more comfortable for her not to know it was science? How do we get away from the myth that science is difficult? How can I help both teachers and students be less afraid of science?

I kept pursuing these questions as I became involved in observing and taking field notes during the second year. Although I was collecting data for a variety of purposes (it seemed like we each had different research questions!), I personally was interested in looking at the interactions between girls and boys and the interactions between students from different racial backgrounds. I remember being told by some of my professors that I should be working in a school with a larger minority population because of my interest in race and gender issues. But I found *plenty* to study in this context, despite the fact that the student population was predominantly white, working class. In fact, one thing I learned from studying this setting is that we need to look in predominantly white school settings to understand better students' perspectives about racial issues.

As I watched the students in Kathy Roth's science class and in Barb and Cheryl's writers' workshop, I had my eyes opened to new ways of looking at knowledge, new ways of sharing attitudes, values, and ideas about how knowledge is constructed. I was particularly interested in the ways in which Kathy's science teaching contrasted with my understandings of conceptual change science teaching from my courses and my reading of the research literature. It seemed to me that a critical aspect of Kathy's science teaching was not highlighted in the conceptual change literature--the notion of the classroom as a community of scientists who construct knowledge together. It was not always the case that Kathy had a clear answer that she wanted the students to

"discover." In fact, in her first science unit, the class never really did come to a definitive answer to their question: Are there more different species of plants and animals in the desert or in Michigan? Kathy used that question to introduce ideas about scientific inquiry as well as ideas about adaptations, structure, function, and species diversity; it suited her just fine that she and the students could not neatly answer the question. Such a question provided a context for exploring with the students approaches to hypothesis generation and criteria for evaluation of evidence.

I saw the same kinds of social construction of knowledge going on in writers' workshop and in Elaine and Corinna's social studies class. These classroom contexts provided a wonderful setting for me to make sense of ideas I was studying in my courses on sociolinguistics and gender and schooling.

Learning in this context also stimulated my thinking about science itself, and I found myself wanting to examine philosophy of science from new perspectives including "Corinna's" feminist perspective and "Kathy's" conceptual change perspective. The LISSS group was a safe place to try talking about some very different ways of thinking about what science might become, how it might become a discipline that would be more inviting to females and other traditional outsiders. The students in these classrooms were learning about science as a cooperative, non-threatening adventure. Would their enthusiasm for science be destroyed when they discovered the "real" world of science to be more competitive, elitist, and hierarchical?

Another critical event was the collaboration with Corinna and Elaine concerning the pig intestines dissection, a traditional event in fifth grade as part of the health curriculum. Normally, I would never have had second thoughts about dissection as part of a health/science curriculum. After all, dissection is a part of science, and it is a part of science that is exciting and appealing to many students. It was only because I had started questioning every pedagogical decision from gender, class, and race perspectives that I encouraged Elaine to reconsider the dissection issue and to bring Corinna, a nonscience person, into our science planning conversations. Is dissection appealing to *all* students? Knowing how Corinna and other nonscience teachers in our group felt, I felt confident that there were probably many students who would not only be uncomfortable with a

dissection but who would be turned off to science if it included a requirement to kill and dissect animals. I wanted to preserve a place in science for students who want to know and understand the world without killing animals. I started wondering what science might look like if it included larger numbers of young scientists who pushed the scientific community to explore alternatives to animal testing. This was one of many occasions when I was challenged to reconsider how science itself might change to include a broader representation of alternative perspectives and to become more inviting to those who have traditionally been outsiders.

I am still struggling with these issues and questions as I do discourse analyses of the fifth-graders' discussions in small groups and as I examine patterns in students' interview responses. To further explore these interests, I am now teaching science to fifth graders, trying to examine ways of creating a classroom environment in which knowledge is socially constructed. I have become so respectful of students' wonderful thinking and ideas that it is sometimes hard for me as a teacher to assert the authority of my knowledge . The students are not at all afraid to challenge explanations that I give or that are written in the texts! I am excited about these challenges, but am trying to figure out how to accept and value them while also challenging and supporting students to consider and understand scientific explanations that might differ from their own. I have come full circle it seems--I started this project thinking I was a science expert, a science resource person. Now I see us all--teachers, students, researchers--as contributing to the construction of scientific knowledge. I wonder how different science might be today if science had been constructed by a wider variety of people.

## Looking Across the Cases: Significance of the (Ongoing) Study

### New Professional Development Model of Reform

The work of this collaborative group provides a new vision of professional development and curriculum reform in elementary science. It is a vision which acknowledges that teaching for understanding in multiple subject areas in elementary schools is an extremely challenging task. Our stories taken as a whole suggest that the traditional focus on science curriculum reform may not be the best starting place for meaningful changes in elementary science teaching. Deeper

learning and understanding may develop if educators are given the support and freedom to study in depth teaching for understanding in an area of the curriculum that is most comfortable and meaningful for them. Barb began with a focus on understanding writing and writing instruction, Elaine started with social studies, and Carol focused on writing and social studies. Cheryl began to collaborate with Carol and Barb who were interested in thinking about their teaching of writing. None of the three teachers was even teaching science during the first year of our work together. They each chose to explore science during our second year of collaborative work. When educators are given such choices and the chance to interact over time with colleagues who are exploring similar issues in other subject matter areas, they will become more genuinely engaged in changing their teaching practice. Given time and support, they will branch out to other subject areas, including science, and they will find ways of connecting with those *other* subject areas that are personally significant for them. For university-based researchers, this model provides a rich context in which to explore teaching and learning. Faced with the day-to-day realities that face elementary teachers who are trying to teach multiple subject areas, researchers gain insights unlikely to be uncovered in more traditional research settings.

In essence, this model of reform considers educators as learners from a constructivist perspective. The model pays close attention to all participants as learners (teachers, researchers, teacher educators): What prior knowledge and experience does the learner bring? What are areas of interest that are meaningful to the learner? What activities will challenge the learners' thinking without overwhelming and frustrating her? The teacher/learner is then encouraged to become actively engaged in her learning through choices about how she will personally engage in addressing the issue of changing her teaching practice so it better supports students in developing meaningful understandings. The teacher/learner has choices in defining appropriate starting points and assessing readiness to branch out to new areas. There is no assumption in this collaborative model that every learner will reach the same understandings at the same point in time. Quite the contrary, it is assumed that each participant is making different sense of shared activities and that each participant will develop in different ways.

Such an orientation to professionals as learners contrasts with traditional reform models. In traditional models of reform, agendas are set by others and placed in the laps of educators. Educators may not be ready to change their science teaching practice, for example, but it has been decided for them--by science educators, by the state--that they will change . . . now! These learners, who are not willingly entering this learning setting, are then given information about how they should change their science teaching and are expected to use this information successfully and immediately. There is no such thing as patience when state assessment tests loom on the horizon or when a state law requires core curriculum documents by a certain date or else funding for the school will be cut. Workshops are set up, and products (goal statements, unit plans, curriculum objectives) are demanded. The "learners" get the work done just like obedient students in work-centered classrooms. They really don't have any choice. They produce these products not for themselves and their learning but to please others--the principal, the state, the public, the "experts."

It is not surprising that such efforts do not radically change teachers' ways of thinking about science and science teaching, just as it is not so surprising that students who are disconnected in classrooms do not really come to understand important ideas in meaningful ways when the focus is on getting assignments done efficiently rather than on learning. Like students in traditional classrooms, teachers may learn some important sounding words like "understanding," "conceptual change," "constructivism," "cooperative learning," but these ideas do not transform their teaching and professional orientation. Like words memorized for a science test, they sound good to others but are used more often to justify existing practice rather than to transform it. These school-smart educators do well in the public eye just like good memorizers do well in school. But their professional efforts have not been liberating, transforming experiences. They are not developing deep and meaningful understandings of science and science teaching.

Key features of this collaborative group. Although the structure of our model--with its emphasis on school-university collaboration and its focus on restructured teacher time for thoughtful study and reflection--was critical in enabling each of us to undergo significant conceptual change in our thinking about science and science teaching, these structural aspects of

our model do not assure such powerful and liberating learnings for professionals. As we study our changes and growth over time, we are trying to identify the key features of this restructured context that enabled the science avoiders to choose to venture into science and that challenged the thinking of our science educators. What enabled this context to be a genuine learning setting for our professional development?

First, we would point to the importance of creating a collaborative group in which the focus is on the learning of all participants. It was critical that each participant in the group came to believe that she had something to contribute to the group and that she could learn from the multiple perspectives of the other participants in the group. For our work to become genuinely collaborative, we had to abandon traditional images of university professors as the experts who would come in and "train" the teachers. Building a community of trust in which each of us could admit publicly our fears and insecurities, breaking down barriers of defensiveness, and creating respect for each other did not happen overnight. There had to be a lot of listening and efforts to understand the others' culture and concerns. There were many times of frustration and even pain as each of us wondered whether our ideas were really being listened to and considered. It took a long time for the teachers in our group to accept that the university people really didn't have the answers and that they really did value the knowledge the teachers brought to the group (we are still working on this!). There were times of frustration for the university participants when they felt like their questions and interests were not shared by the school-based educators. These frustrations and difficulties in building and maintaining trust were significant and are worthy of attention in more detail--but we leave that for another paper!

We have identified the following as key features of our collaborative work that enabled us to develop a learning setting in which each participant feels like an important contributor and in which each participant can point to significant growth as a result of the collaborative efforts:

- Constructing a group that represents and values multiple perspectives and subject matter area interests
- Working patiently over time to develop shared goals and understandings about professional development and shared commitment to changing and improving learning opportunities for children

- Supporting each participant in beginning with a focus on one subject matter area at first--allowing the individual to choose when she is ready to explore another area
- Working side by side in both elementary and university classrooms--being jointly responsible for planning, teaching, and studying elementary students and prospective teachers
- Maintaining an inquiry/research orientation but letting research questions and directions evolve over time; a collaborative definition of research problems
- Patience and a willingness to be responsive to the needs of others in the group
- Willingness to get to know each other as humans with lives outside this professional context and with professional histories that influence our interactions
- Time

New Vision of Research in and for Teaching

Looking across the cases of participants' growth, it is clear that a variety of important questions and insights about science teaching and learning grew out of this collaborative work. These are issues that the group is writing about and talking about in professional presentations. These are not issues that arose only for particular participants but are ones that emerged as important for all participants. The list includes the following:

- The importance of creating genuine learning (vs. work) classroom communities; the danger of putting conceptual change teaching practices into work-centered classrooms
- Racial and gender issues in science teaching
- The importance of developing "wondering of the mind" of all participants (students, teachers, researchers) in science classrooms
- The role of writing and discourse (in large and small group contexts) in science learning
- Meaningful versus "cute" connections across science, social studies, and language arts; challenging the limitations of the traditional focus on integration between science and math

As we write about our work and present our ideas at conferences, we are becoming increasingly aware of ways in which this kind of teaching and research challenges traditional paradigms in which research and teaching are represented in two distinct cultures, each with its own set of journals and professional meetings. When we present at research-oriented meetings, our work is often viewed as too teacher-focused--too "folksy." Our presentations at teacher conferences, on the other hand, are perceived by many as too theoretical, too much focused on thinking and not enough on action: "Just give me some ideas about what I can do in class Monday." We believe that we are exploring a fascinating intersection between research and teaching--our research is conducted both *in* and *for* teaching. As a result, it does not always follow the rules of educational research. But we would argue that this does not mean it should be any less valued as a significant form of educational research.

The ongoing work of this group provides understandings of what is possible in terms of educators' and students' learning when teacher and researcher roles are restructured, merged, and recreated. The educators in these classrooms were able to explore deeply problems in science, in teaching, and in learning. The school- and university-based participants in this collaborative venture all describe this experience in stark contrast with the kinds of learning and professional development experiences they have had in other settings. It *is* possible for nonscience-oriented educators to develop deep and personally meaningful understandings of children, of teaching, and even of science in restructured settings like this one. In this collaborative setting in which multiple perspectives are represented, it *is* possible for university science education researchers to gain new insights and understandings about science and science teaching that are not likely to develop in more traditional science education research and curriculum development contexts.

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